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IN-SERVICE EVALUATION OF 2090 ALUMINUM-LITHIUM ALLOY ON F/A-18 AIRCRAFT

J. Kozol, E.S. Tankins, J.J. Thompson, C.E. Neu
Air Vehicle and Crew Systems Technology Department (Code 606)
NAVAL AIR DEVELOPMENT CENTER
Warminster, PA 18974-5000

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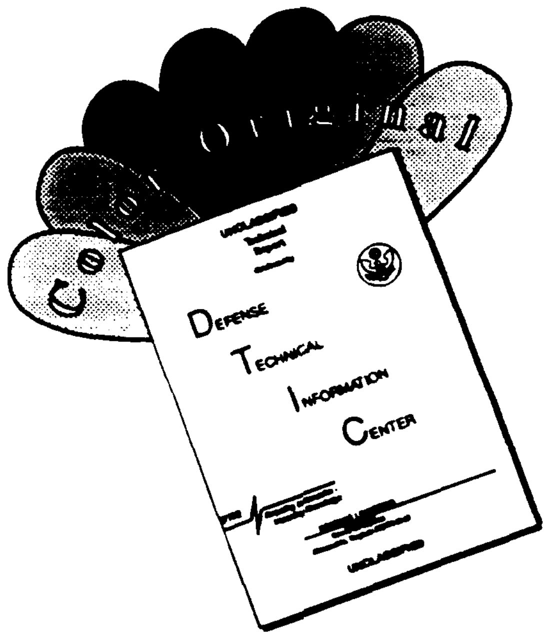

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13. ABSTRACT *(Maximum 200 words)*
Al-Li alloys can provide reduced weight and increased stiffness as replacements for conventional aluminum alloy aircraft components. A study was conducted to compare the performance of 2090 Al-Li and 7075 Al alloys in-service on Navy aircraft, during shipboard exposure and in laboratory accelerated tests. Results from this investigation indicated that no additional maintenance was required during in-service exposure and that the corrosion behavior of the two alloys in laboratory tests and during shipboard exposure was comparable.

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McDonnell Aircraft Company supplied the aluminum alloy access covers used in these tests and gratitude is expressed to Mr. D.W. Marquart and Dr. K.K. Sankharan for their assistance.

INTRODUCTION

Aluminum-lithium (Al-Li) alloys offer the potential for 8-10% reduction in structural weight on a gage-for-gage substitution for conventional high strength aluminum alloys, as well as enhanced elastic modulus and improved fatigue resistance. Extensive research and development efforts have been conducted on promising aluminum-lithium alloys (1). Several of the alloys are now commercially available and are important candidates for aerospace applications.

This test program represents the first application of an aluminum-lithium part on U.S. Navy aircraft. McDonnell Douglas Corporation identified a non-structural component (ALR-45 Detector Access Cover) for potential material substitution on F/A-18 aircraft for purposes of fleet evaluation. McDonnell Douglas fabricated 12 aluminum-lithium (2090-T8E41) covers and 12 conventional aluminum (7075-T6) covers, which they provided to the Navy for evaluation. The covers were manufactured under their IRAD program. The Naval Air Systems Command approved in-service evaluation of the Al-Li covers (2).

The purpose of this study was to conduct an in-service evaluation and to compare the performance of Al-Li and conventional aluminum covers during exposure aboard ship on a corrosion test rack and in laboratory accelerated corrosion tests.

MATERIALS

The alloys used in this evaluation were conventional 7075-T6 aluminum, which is the bill of materials for access covers currently on the F/A-18 aircraft, and 2090-T8E41 aluminum-lithium. Right side and left side covers of each alloy were fabricated and painted by McDonnell Aircraft Co., St. Louis, Mo. The paint system consisted of MMS 425 epoxy primer on the interior and exterior, followed on the exterior with one topcoat of MMS 420 polyurethane and one MIL-C-83286 topcoat.

PROCEDURES

IN-SERVICE EVALUATION

Access covers were installed on six F/A-18 aircraft at NAS Cecil Field, and on two F/A-18 aircraft at MCAS Beaufort. Two covers were installed on each aircraft, one made of conventional aluminum alloy 7075-T6 and one made of aluminum-lithium alloy 2090-T8E41. The aircraft at NAS Cecil Field were carrier deployed, and the aircraft at MCAS Beaufort were land based. Distribution and identification of the access cover panels on the aircraft is described in Table 1. Figure 1 illustrates the access cover installation on an F/A-18 aircraft.

ACCELERATED CORROSION TESTING

Three types of accelerated corrosion tests were conducted, each according to ASTM standards. One access cover of each alloy was exposed in each accelerated test environment. Sulfur dioxide (SO_2) salt spray testing was conducted per ASTM G85.A4. In this test, a 5% solution of sodium chloride was sprayed continuously in the chamber with SO_2 gas introduced for one hour, four times per day. Temperature in the chamber was maintained at 35°C (95°F). Cyclic acidified salt spray (MASTMAASIS) testing was conducted per ASTM G85.A2, with wet bottom and dry bottom. In these tests, pH of the 5% sodium chloride solution was maintained at 2.8-3.0 and a repetitive cycle of spray, dry air purge and high humidity soak was used. Temperature in the chamber was maintained at 49°C (120°F). For the wet bottom test, water was allowed to collect in the bottom of the salt spray chamber. For the dry bottom test, the exit valve was left open and water drained from the bottom of the chamber.

Naval aircraft exterior surfaces are protected in service by an organic coating system designed to prevent and inhibit corrosion. The access covers subjected to accelerated corrosion testing were scribed with an "X" down to the bare substrate in order to determine the behavior of the bare substrate alloys in the event of loss of the environmentally protective coating. These panels were scribed initially on the left half with an "X" down to the bare substrate, as shown in Figure 2, and mounted in a rack at 15 degrees to the vertical. After two weeks exposure, the right half of each panel was scribed and the test continued for another two weeks. In this manner, the left half of each panel revealed the total effects of four weeks exposure and the right half simultaneously revealed the effects of two weeks exposure at the scribed areas.

SHIPBOARD CORROSION TESTING

One each of the 7075-T6 and 2090-T8E41 access covers were scribed on the left half as described above and exposed to the environment on an aircraft carrier. A rack containing the access covers was placed on the U.S.S. Independence and retrieved for examination after one deployment of the carrier.

RESULTS AND DISCUSSION

IN-SERVICE EVALUATION

After two years exposure on carrier based and land-based aircraft, all of the access covers were in good condition, with no visible evidence of corrosion or other damage. No special maintenance was required on any of the panels. A typical Al-Li access cover is shown in Figure 3. Extended exposure of the access covers on F/A-18 aircraft is being continued.

ACCELERATED CORROSION TESTING

Appearance of the 2090 and 7075 alloy access covers after three types of accelerated corrosion tests is shown in Figures 4 through 9. It can be seen that blistering occurred only along the scribe lines. Comparison of the two alloys after each test indicates more blistering for the 7075 alloy than for the 2090 aluminum-lithium alloy, especially after 4 weeks (672 hours) exposure. It is apparent that the greatest amount of blistering occurred for both alloys in the SO_2/salt spray test, Figures 8 and 9. This test most closely simulates the carrier environment, specifically the acidified atmosphere resulting from jet engine and stack exhaust gases (3).

The corrosion tested access covers were stripped chemically, revealing the presence of corrosion along the scribe lines. There was no evidence of pitting corrosion or exfoliation. The panels are shown after stripping in Figures 10 through 12. For comparison, the 7075 and 2090 panels are shown side by side for each test.

The covers were evaluated according to ASTM D 1654, "Standard Methods of Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments". Scribed areas were rated as prescribed in Table 1 of ASTM D 1654, which assigns a rating number from 0 to 10 to each area of corrosion, depending on its mean creepage from the scribe line. A rating of 10 indicates no measurable attack. The percentage of the total length of scribe line assigned to each rating was determined and then multiplied by the rating. These factors were then added to obtain a cumulative rating of corrosion failure at the scribe for each specimen. Ratings of failure at the scribe lines are shown in Table 2.

In general, there were almost no measurable effects shown for either alloy in the cyclic acidified salt spray wet bottom test. This is reflected in the ratings of failure at the scribe lines, Table 2. In the cyclic acidified salt spray dry bottom test, the result is basically the same, with a slightly greater amount of corrosion occurring in the 7075 substrate as compared to the 2090 substrate after 4 weeks. The small amount of corrosion on the 7075 cover after 4 weeks exposure can be seen in Figure 11. According to ASTM D 1654, this resulted in a slightly lower rating of 9.6, compared to 9.9 for the 2090 alloy after 4 weeks exposure. For the two cyclic acidified salt spray tests, the differences in corrosion ratings at the scribe lines are minute and the two alloys are considered to have equivalent behavior.

The severity of the SO_2/salt spray test is reflected in the appearance of the covers, as shown in Figure 12. Corrosion in the 2090 substrate was more uniform than in the 7075, although it extended over a greater area of the scribe lines. This is reflected in the lower rating for the 2090 after 4 weeks exposure (Table 2). Numbers in parentheses next to the ratings for the SO_2/salt spray tests indicate the range of corrosion ratings along the scribe lines. These numbers show that greater individual areas of corrosion occurred for the 7075 alloy than for the 2090 alloy (as shown in Figure 12). For this test, as for the other accelerated corrosion tests, there were no distinct differences in the overall performance of both alloys.

SHIPBOARD CORROSION TESTING

In shipboard corrosion testing, 7075-T6 and 7075-T76 plate and cadmium plated 4130 steel sheet specimens are included as controls to permit assessment of the severity of the environment. The lack of corrosion of the controls after 6 months deployment on the U.S.S. Independence indicates the environment was not sufficiently severe for an accurate assessment of susceptibility to environmental degradation.

Appearance of the access covers exposed to the carrier environment is shown in Figure 13. The 7075 alloy cover shows a very slight effect at the scribe lines and the 2090 alloy cover shows no attack at all. Because of the lack of significant corrosion of either alloy, the covers were not stripped and will be redeployed aboard ship for further comparison of corrosion behavior. At this point, the performance of the two alloys appears to be equivalent.

CONCLUSIONS

1. In-service exposure of 2090-T8E41 aluminum-lithium alloy access covers on F/A-18 aircraft has resulted in no additional maintenance requirements.

2. Accelerated corrosion tests and shipboard exposure tests have shown that the corrosion behavior of the 2090-T8E41 alloy is comparable to that of the 7075-T6 alloy in sheet applications.

RECOMMENDATIONS FOR FUTURE WORK

It is recommended that in-service exposure testing continue on F/A-18 aircraft, along with shipboard corrosion tests, to confirm the results of laboratory accelerated tests.

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1. E.W. Lee, C.E. Neu and J. Kozol, "Al-Li Alloys and Ultra High -Strength Steels for U.S. Navy Aircraft," JOM, Vol. 42, No. 5, May, 1990.

2. NAVAIR LTR SER AIR5304 B4/7-0199, 6 Oct 88.

3. S.J. Ketcham and E.J. Jankowsky, "Developing an Accelerated Test: Problems and Pitfalls" Laboratory Corrosion Tests and Standards, ASTM Special Technical Publication 866, American Society for Testing and Materials, Philadelphia, 1985.

Table 1. Identification Of Access Covers On F/A-18 Aircraft.

Custodian	Bureau Number	ACFT Side Number	Cover Material	Panel ID	Part Number	Side
VFA-82	163427	304	7075-T6 2090-T8E41	1 12	74A-313103-2003 SIA-313103-5004	L R
VFA-82	163438	302	7075-T6 2090-T8E41	11 1	74A-313103-2004 SIA-313103-5003	R L
VFA-82	163442	303	7075-T6 2090-T8E41	9 11	74A-313103-2003 SIA-313103-5004	L R
VFA-86	163437	401	7075-T6 2090-T8E41	6 10	74A-313103-2003 SIA-313103-5004	L R
VFA-86	163439	402	7075-T6 2090-T8E41	7 5	74A-313103-2004 SIA-313103-5003	R L
VFA-86	163443	400	7075-T6 2090-T8E41	8 2	74A-313103-2004 SIA-313103-5003	R L
VMFA-312	163173	09	7075-T6 2090-T8E41	2 9	74A-313103-2003 SIA-313103-5004	L R
VMFA-312	163171	07	7075-T6 2090-T8E41	10 6	74A-313103-2004 SIA-313103-5003	R L

Table 2. Ratings Of Failure At Scribe Lines Per ASTM D 1654.

ASTM G85 Testing	2 WEEKS		4 WEEKS	
	2090	7075	2090	7075
Cyclic Acidified Salt Spray, Wet Bottom	10	9.9	10	9.9
Cyclic Acidified Salt Spray, Dry Bottom	10	9.9	9.9	9.6
SO_2/Salt Spray	9.0(8-10)	9.2(7-10)	8.1(7-10)	9.0(6-10)

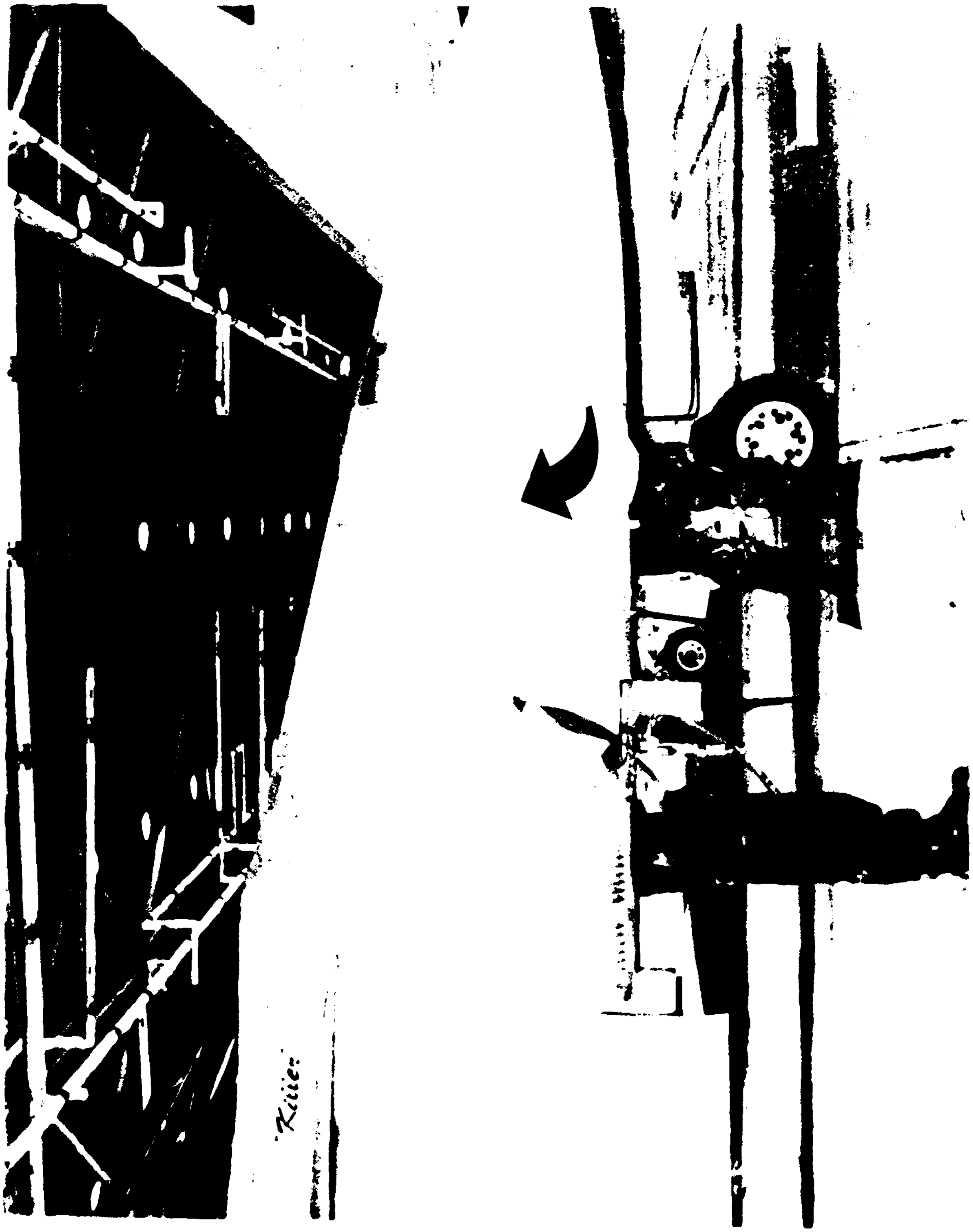


Figure 1. Access Cover Installed On F/A-18 Aircraft.

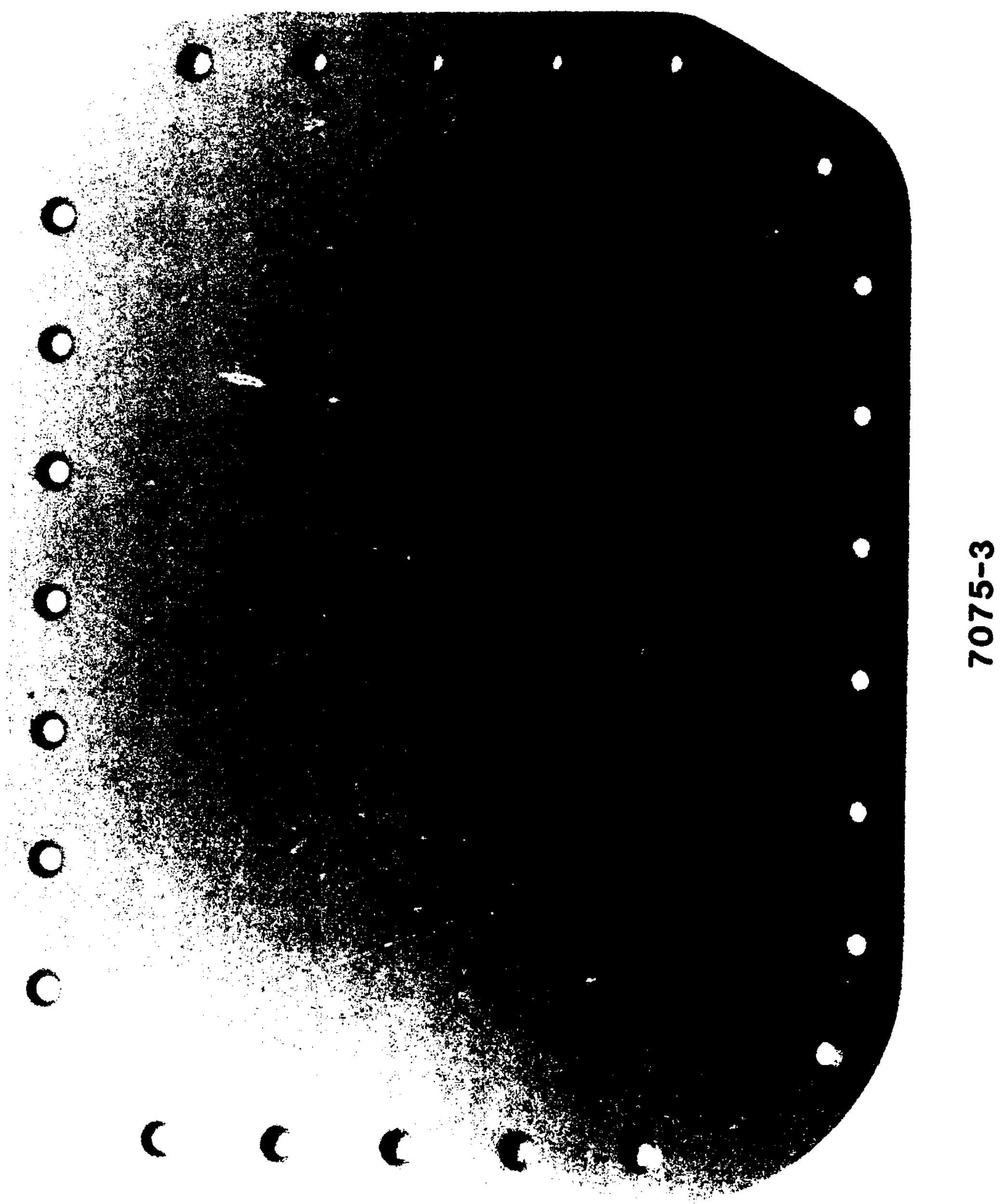


Figure 2. Access Cover Scribed For Corrosion Testing.

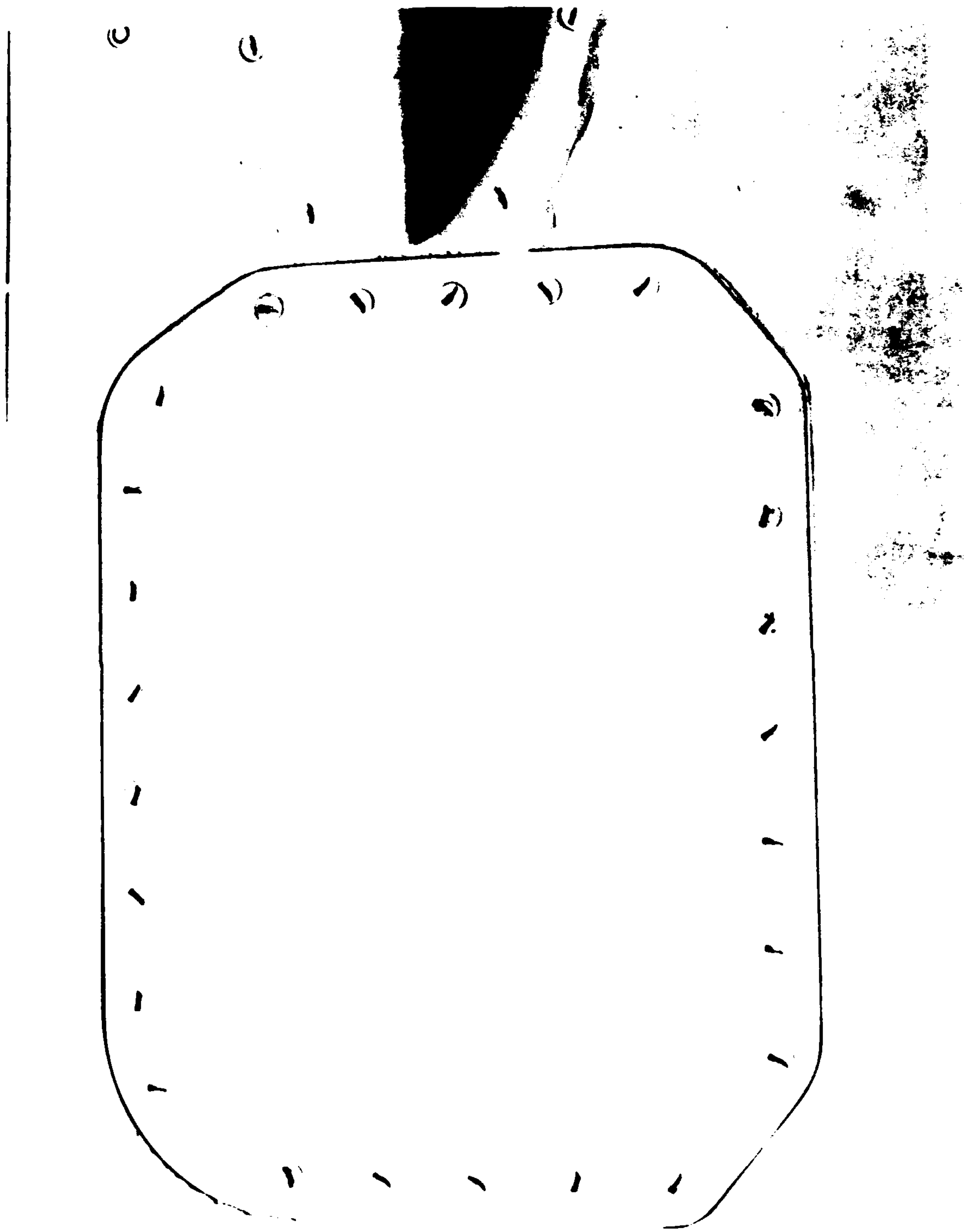


Figure 3. Access Cover After Two Years Exposure On F/A-18 Aircraft.

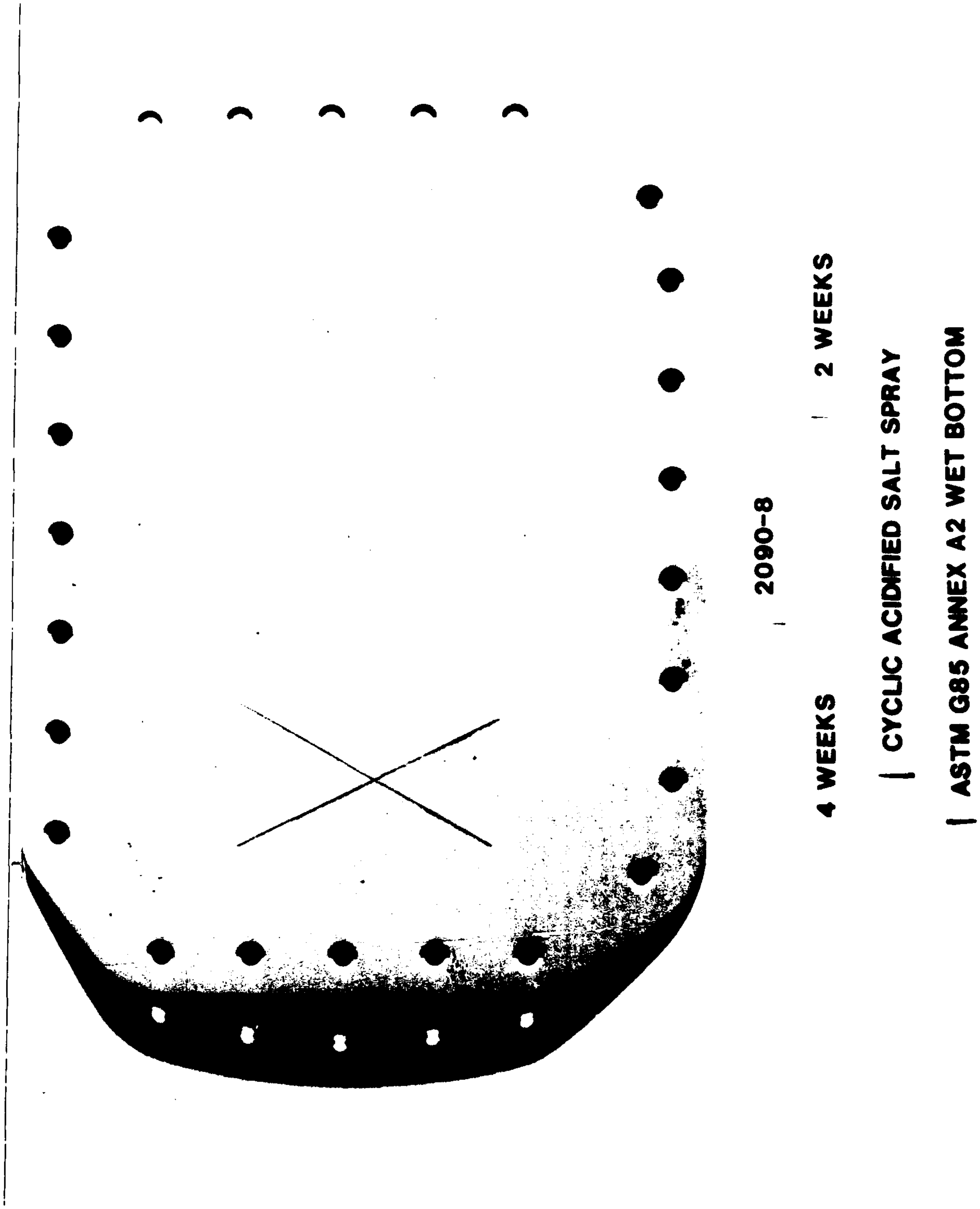


Figure 4. 2090 Alloy Cover After Four Weeks In Cyclic Acidified Salt Spray, Wet Bottom Test.

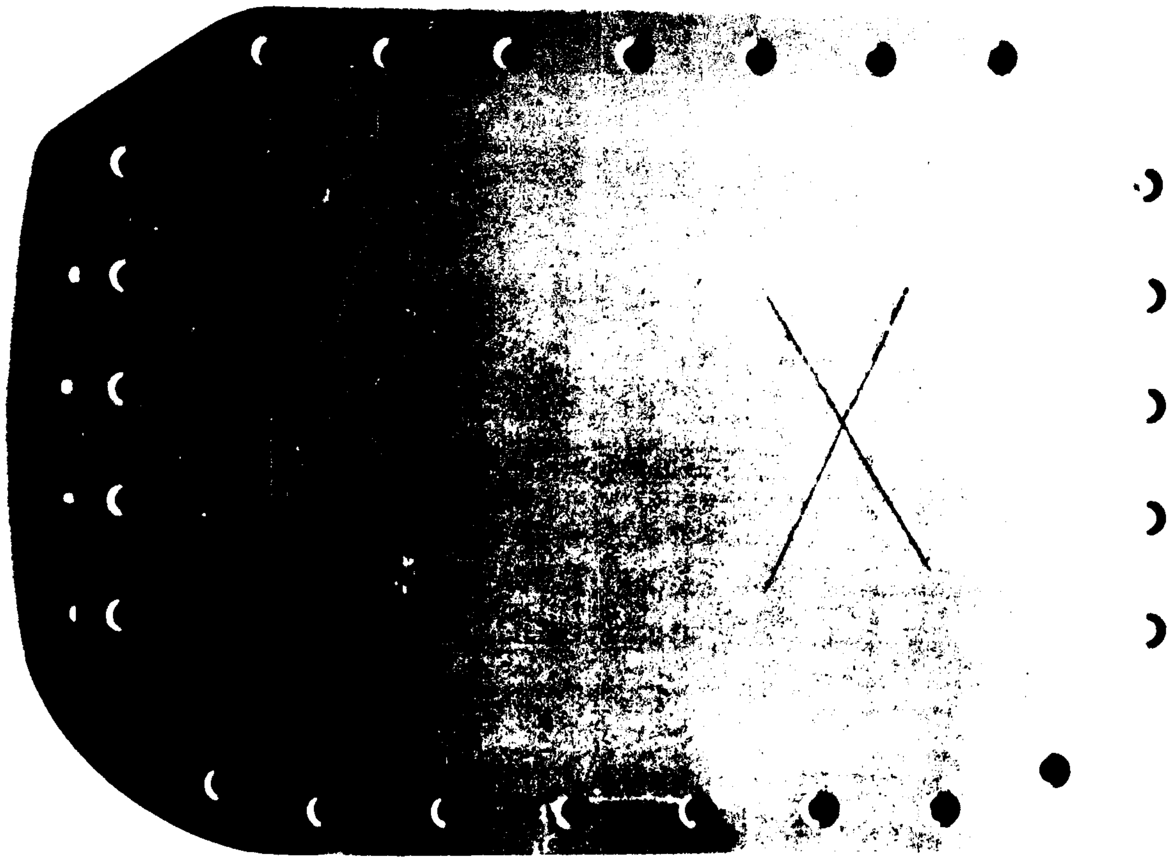
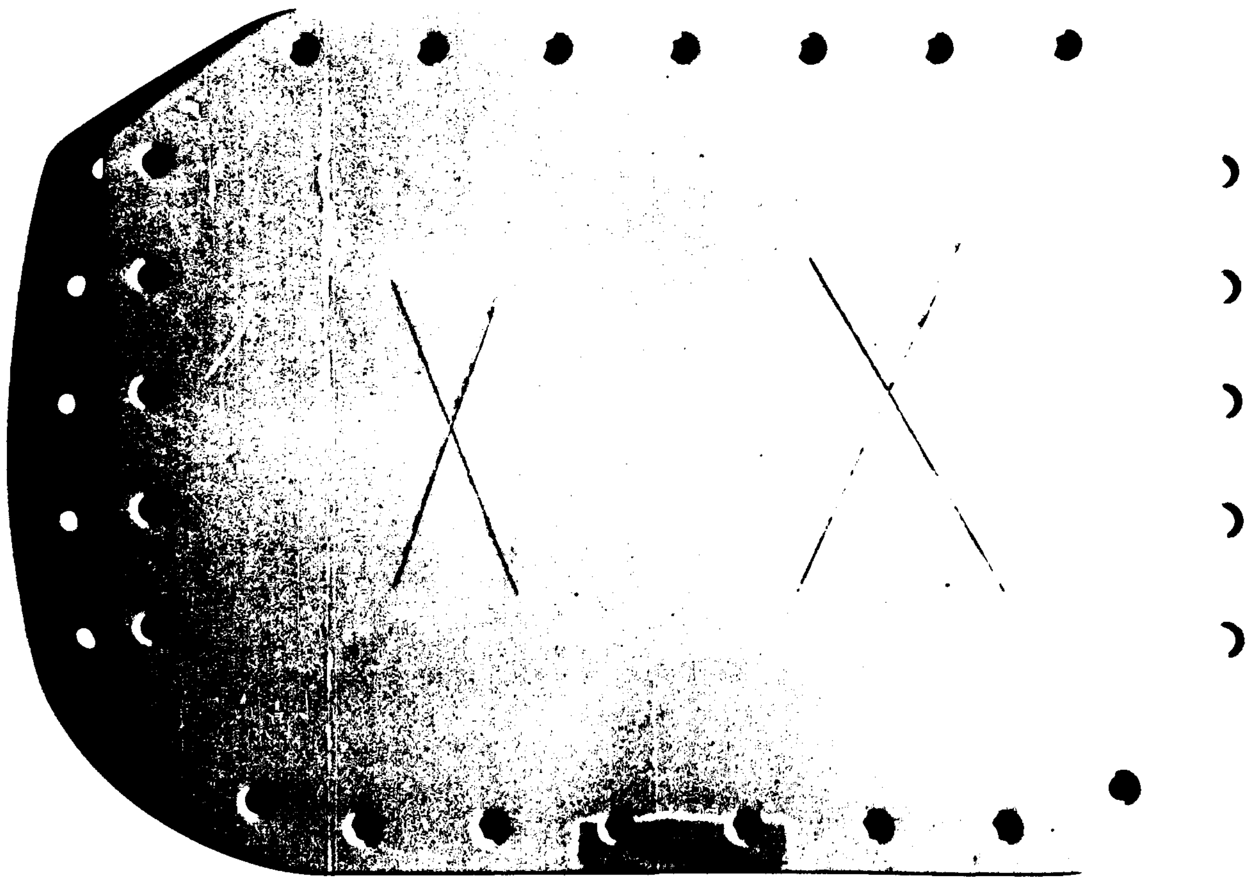


Figure 5. 7075 Alloy Cover After Four Weeks In Cyclic Acidified Salt Spray, Wet Bottom Test.



2090-4

4 WEEKS 2 WEEKS

CYCLIC ACIDIFIED SALT SPRAY

ASTM G85 ANNEX A2 DRY BOTTOM

Figure 6. 2090 Alloy Cover After Four Weeks In Cyclic Acidified Salt Spray, Dry Bottom Test.

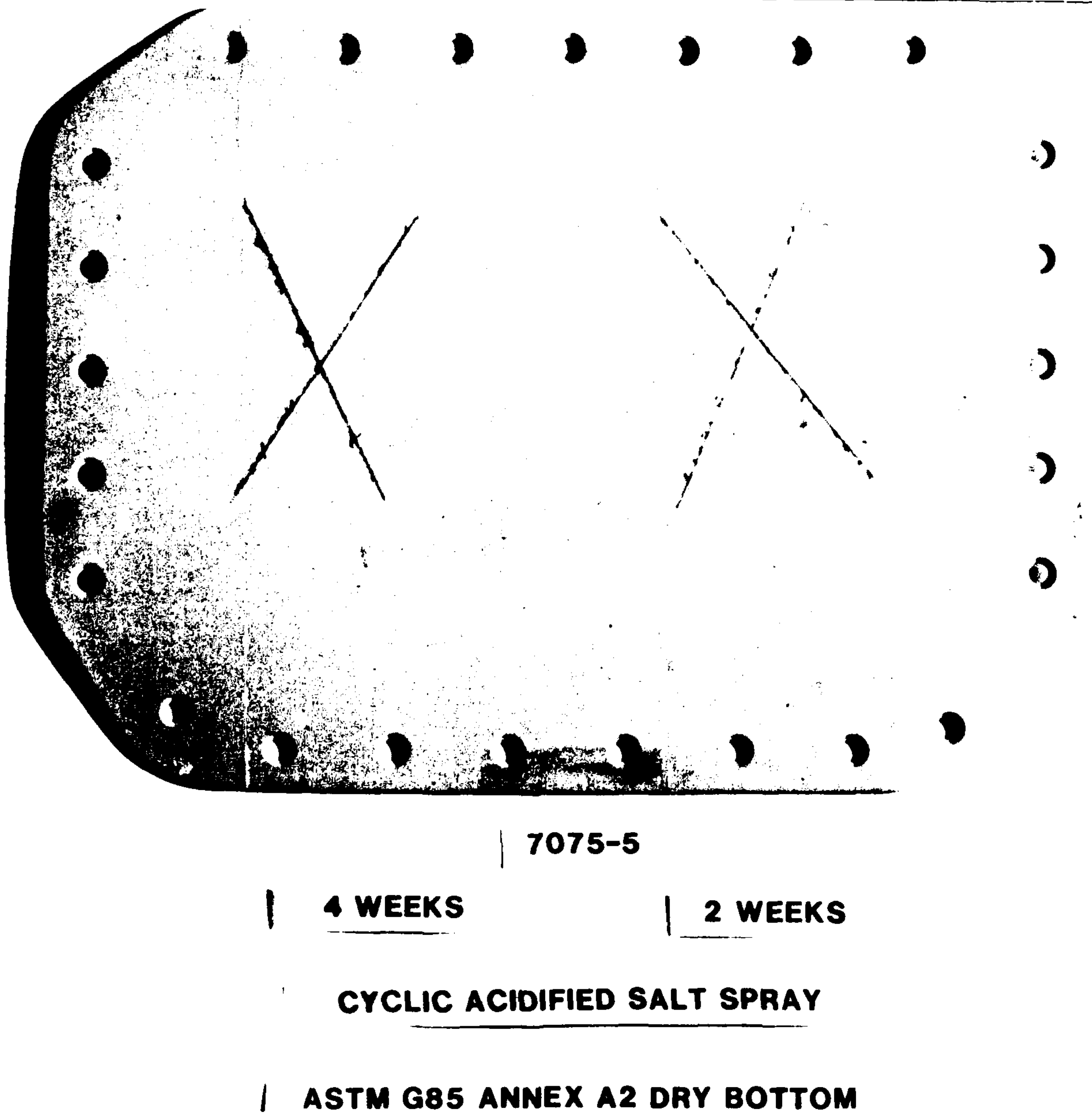


Figure 7. 7075 Alloy Cover After Four Weeks In Cyclic Acidified Salt Spray, Dry Bottom Test.

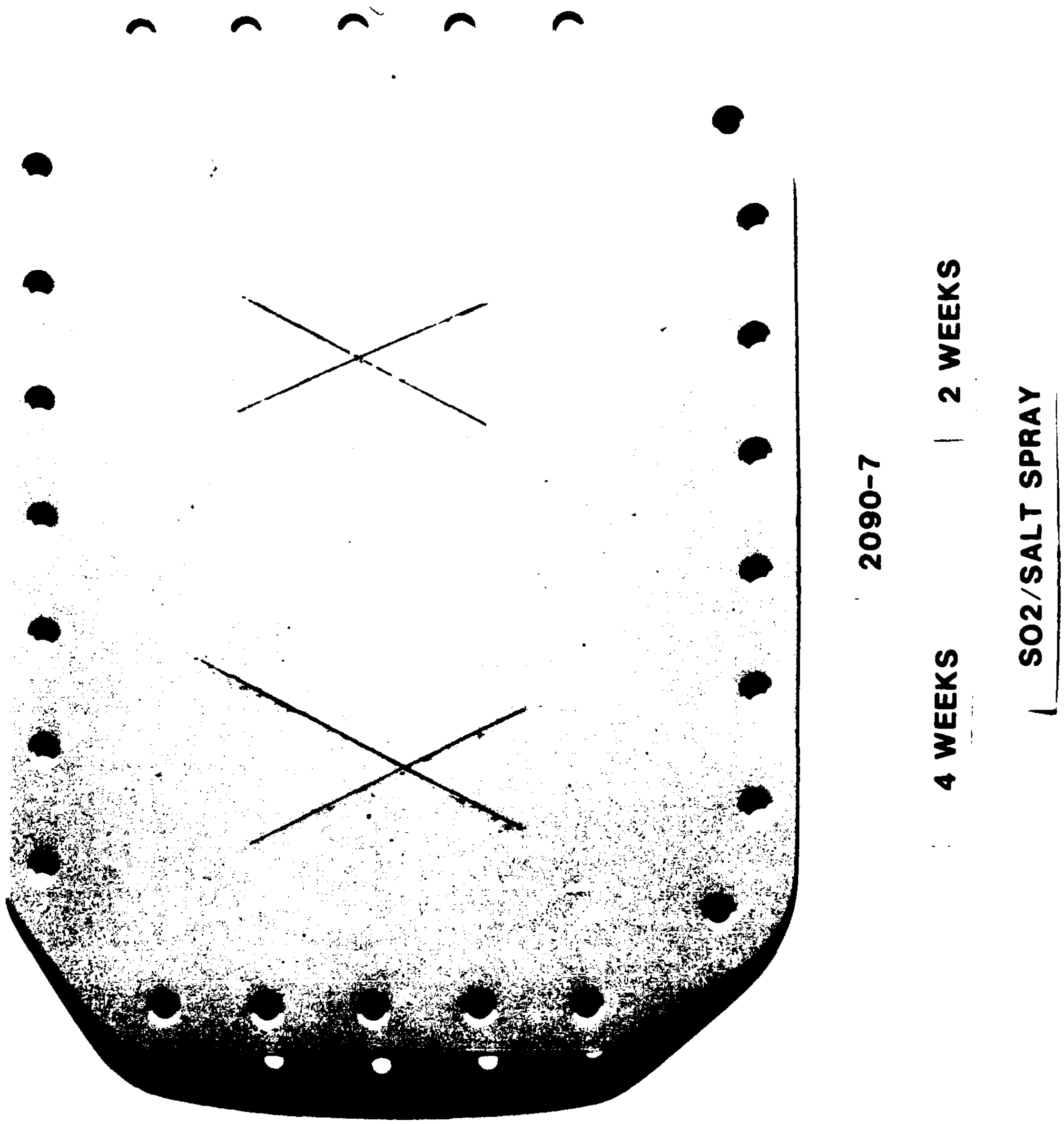
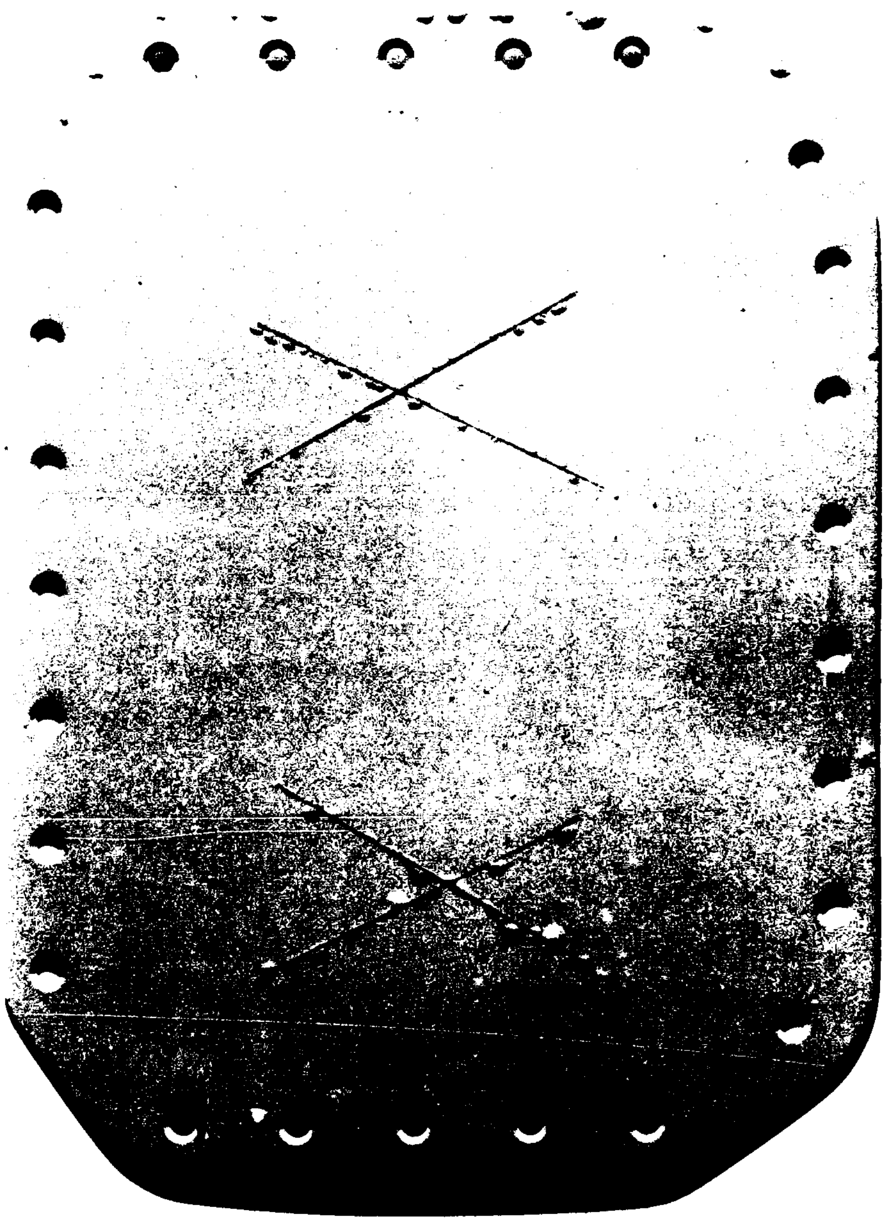


Figure 8. 2090 Alloy Cover After Four Weeks In SO_2/Salt Spray Test.



7075-4

4 WEEKS

2 WEEKS

SO2/SALT SPRAY

ASTM G85 ANNEX A4

Figure 9. 7075 Alloy Cover After Four Weeks In SO_2/Salt Spray Test.

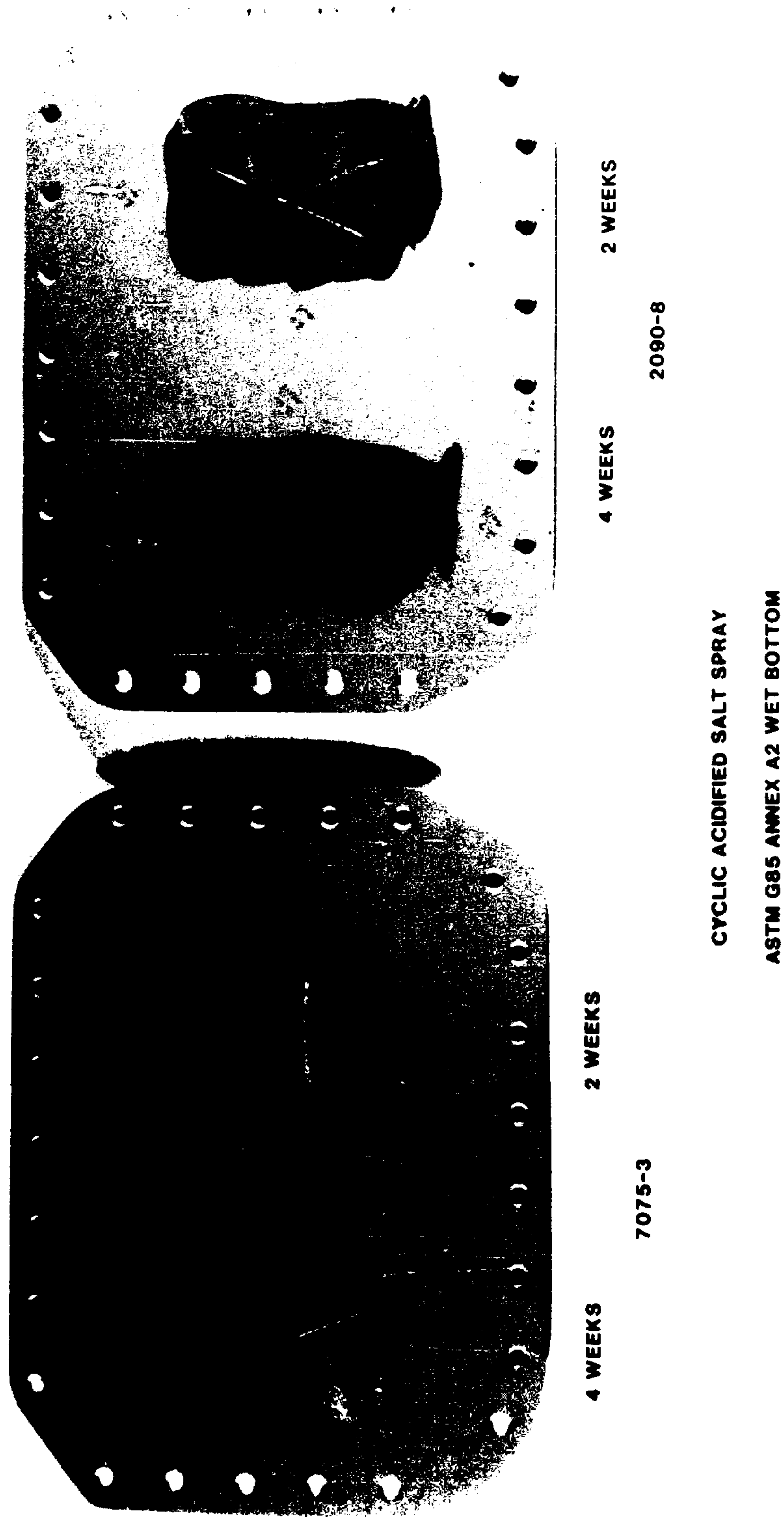


Figure 10. Access Covers Stripped After Cyclic Acidified Salt Spray/Wet Bottom Test.

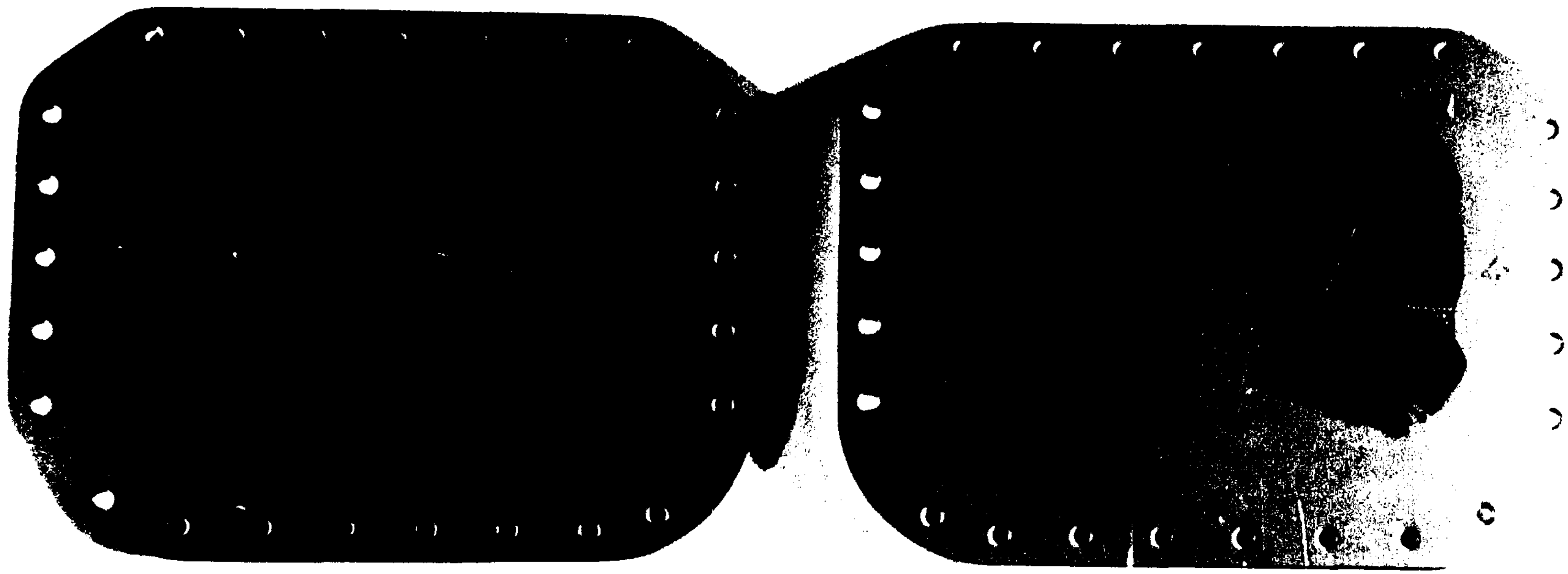


Figure 11. Access Covers Stripped After Cyclic Acidified Salt Spray/Dry Bottom Test.

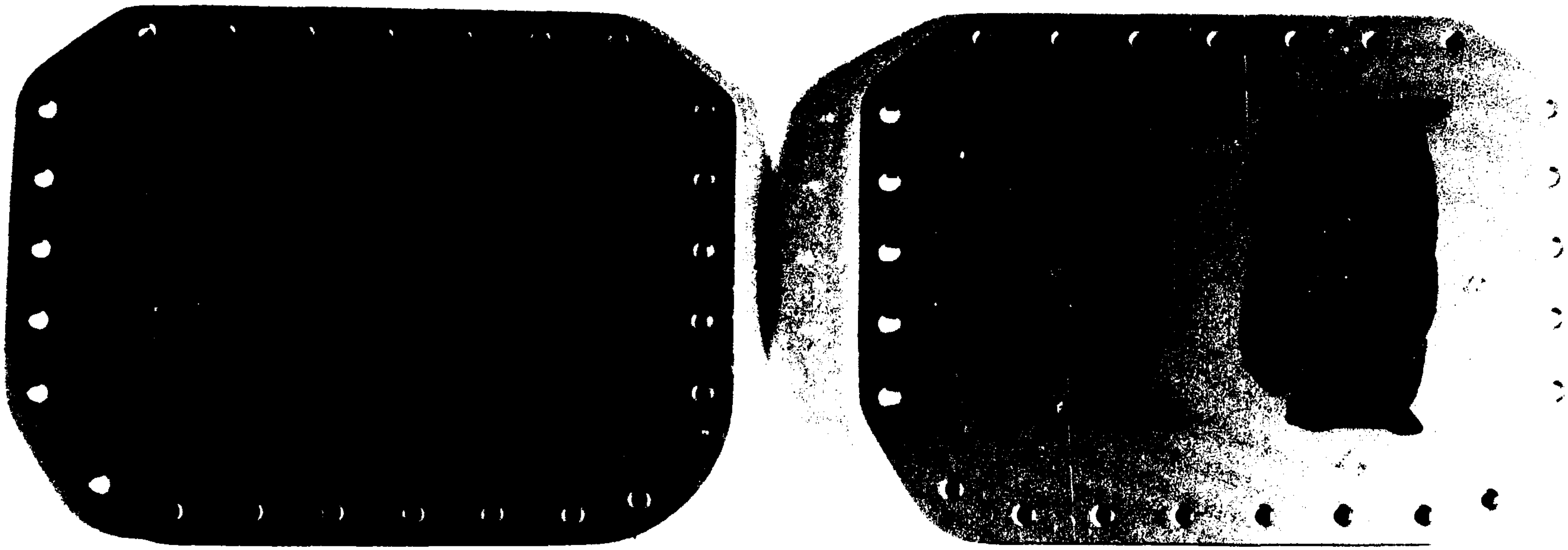


Figure 12. Access Covers Stripped After SO_2/Salt Spray Test.

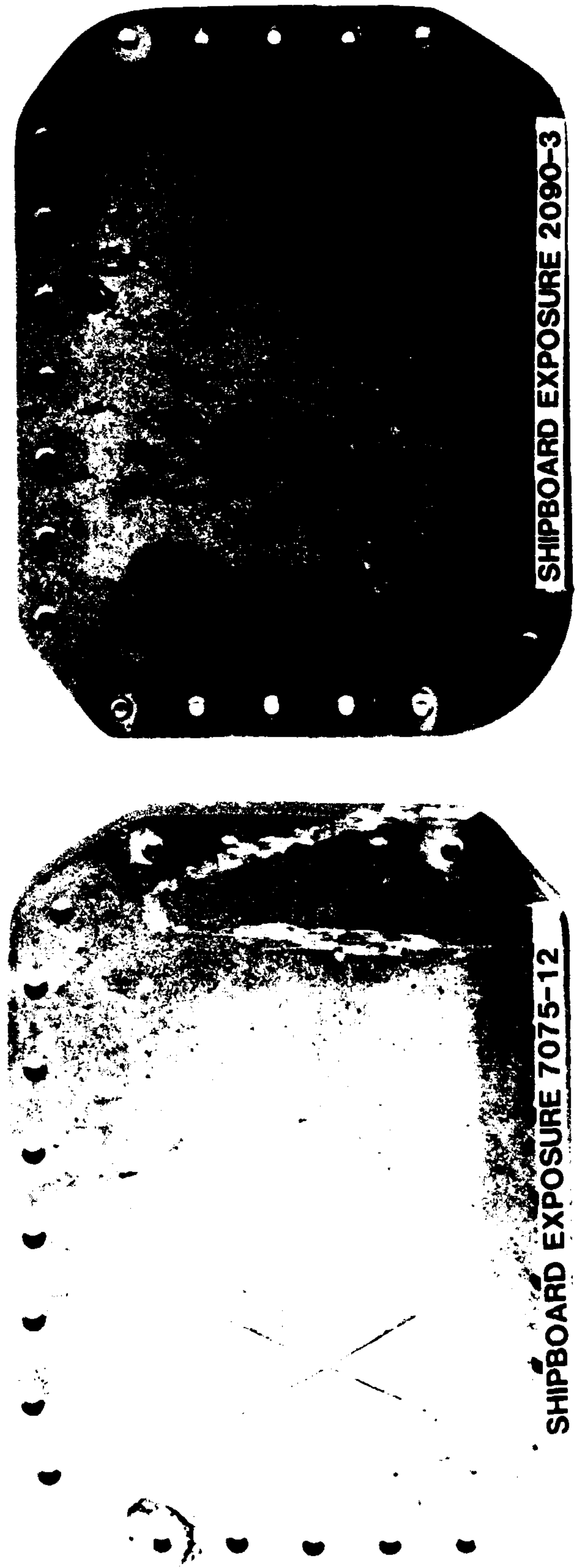


Figure 13. Access Covers After Shipboard Exposure.

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